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Optimum Temperatures for Growth of Southern Rocky Mountain Engelmann Spruce and Douglas-fir Seedlings

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Because requirements of the two species are similar to each other and similar to that of coastal Douglas-fir, they all can be grown together. However, requirements are sufficiently different from ponderosa pine to warrant a separate greenhouse.

Keywords: *Picea engelmannii*, *Pseudotsuga menziesii*, greenhouse, nursery, artificial regeneration

Introduction

To efficiently produce seedlings in greenhouses, it is important to know the optimum day and night temperatures for the species and ecotypes to be grown. These optimum temperatures should be determined under conditions as close as possible to those expected in the production nursery.

Although there is considerable information about the culture of Douglas-fir (*Pseudotsuga menziesii* var. *menziesii* (Mirb.) Franco) on the West Coast (Brix 1971), there is some doubt about its applicability to Rocky Mountain ecotypes (var. *glaucoides* (Beissn.) Franco). Temperature data for Engelmann spruce (*Picea engelmannii* (Parry)) (Helmers et al. 1970) were collected under conditions quite different from those expected in a greenhouse nursery. Previous work has shown that response to temperature can be very different under different day lengths and lighting regimes.²

The objective of this study was to determine the response of Engelmann spruce and Douglas-fir of central and southern Rocky Mountain seed sources to 16 com-

binations of day and night temperature, under conditions closely matching those planned for the greenhouse nurseries at Mt. Sopris in Colorado and Albuquerque, N. Mex.

Materials and Methods

To extrapolate the results of this study to production greenhouse conditions, all conditions other than temperature were held to expected greenhouse conditions as closely as possible. Size 8A Styroblocks³ were cut into sections with 16 cavities and filled with a 1:1 peat-vermiculite mix. The peat was a Canadian sphagnum with a Von Post consistency of about 2 (Robinson and Lamb 1975). The vermiculite was "attic fill" with a 3- to 5-mm particle size.

Four seed lots of Engelmann spruce and two of Douglas-fir were selected so as to represent a wide variation in latitude within the range of these two species; therefore, any important differences in response to temperature between seed sources within species would be likely to show up.

Three seeds were planted in each cavity, and the seeded blocks were assembled on a table, were soaked with water, and were covered with clear polyethylene to

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²Tinus, R. W. 1976. Growth of white spruce and lodgepole pine under various temperature and light conditions. Unpublished report to Alberta Department of Energy and Natural Resources. 49 p.

³Mention of trade names is for specificity and the convenience of the reader, and does not imply endorsement by USDA to the exclusion of equally suitable products not mentioned.

keep the surface moist until germination. A total of 16 blocks of each seed source of each species was seeded.

After germination, the plastic was removed, and four blocks per seed source were moved into each of four Percival ³HL-60 growth chambers programmed as follows:

| | |
|------------------------|--|
| Timing: | Day: 4:30 p.m. – 8:00 a.m. (15.5 h) |
| | Night: 8:00 a.m. – 4:30 p.m. (8.5 h) |
| Lights: | Day: Sodium plus improved mercury arc at 60,000 lux |
| | Night: No light except 1 minute every 15 of incandescent light at 430 lux throughout the night to make a 24-hour photoperiod |
| CO₂: | Day: 1200 ± 100 ppm |
| | Night: 350 ± 25 ppm |
| Humidity: | Day 70 ± 10% |
| | Night 80 ± 10% |
| Temperature: | Growth Chamber No. 1 2 3 4 |
| | Day: (°C) 28 23 18 13 |
| | Night: (°C) 28 23 18 13 |

The Styroblocks were painted around the sides with a color code. The top color indicated day temperature and the bottom color the night temperature. Twice a day the blocks were sorted among the four growth chambers to produce 16 combinations of day and night temperature, each represented by one block per seed source. Any one block received the same day/night temperature combination throughout the growth period.

After the seed coats dropped and germination was essentially complete, the seedlings were fertilized with a modified Hoagland's solution at every watering. The watering schedule was determined by need (dryness); therefore, the high temperature treatments generally received more than the cooler ones. The nutrient solution was applied in excess at each watering, so that some leaching occurred to insure against salt buildup and to keep the seedlings exposed to roughly constant nutrient conditions.

After the danger of damping off was largely past (age 3 weeks), the seedlings were thinned to one per cavity.

The seedlings were grown until the average tree in the best treatment was about 150 mm tall and an estimated 2 g dry weight (in this experiment, 18 weeks). This is about the size of spruce or fir required for good balance in a styro 8A. The seedlings then were extracted from the containers and growing medium removed from the roots. Height, root collar, caliper, and dry weight were measured.

A two-way analysis of variance with main effects for day and night temperature plus the interaction between them was performed for each measurement on each seed source.

| Source | Degrees of freedom |
|-----------------------|--------------------|
| Day temperature | 3 |
| Night temperature | 3 |
| Day/night interaction | 9 |
| Error | 240 |
| Total | 255 |

The error mean square was used to calculate the coefficient of variability.

Mean height, caliper, and dry weight values for each day/night temperature combination were calculated for each seed source and measurement. These were expressed as a percentage of the largest mean value, and were graphed with day temperature as the abscissa and night temperature as the ordinate. The 90%, 80%, 70%, etc., isolines were drawn by hand by linear interpolation in two dimensions, and allowable ranges and set points were determined, as reported by Tinus and McDonald (1979).

Results and Discussion

The effects of combinations of day and night temperature on height, caliper, and dry weight of the six seed sources are shown in figure 1. The coefficients of variability for height and caliper are 1-2%, and 2-4% for dry weight, which is remarkably low. Because differences approximately double the coefficient of variability are significant at the 5% probability level, a significant difference on the height and caliper graphs would be about one-fourth the distance between contour lines, and for dry weight about one-half the distance between contour lines. This is only approximate, however, because the graphs are hand-drawn. Nevertheless, it is a useful indication of how much confidence can be placed in the temperature information.

Based on the graphs in figure 1 and criteria given by Tinus and McDonald (1979), the day and night temperature set points and allowable ranges were compiled in table 1. For comparison, previously published data on Engelmann spruce (Helmers et al. 1970), Douglas-fir (Brix 1971), and ponderosa pine (Tinus and McDonald 1979) also are included.

The four seed sources of Engelmann spruce appear to be very similar in their temperature requirements and, therefore, are compatible in the same greenhouse. The source from the Bighorn Mountains of Wyoming shows an unusual double optimum. The only other such double optimum reported was found with radiata pine (Helmers and Rook 1973). Fortunately, one of the optima is close to the optima of the other sources of spruce. Compared to Helmers et al. (1970), day temperature optimum is the same, but night temperature requirements are quite different. Night temperature optimum in Helmers' experiment was high and the allowable range was narrow, whereas night optimum of the four sources in this test was about the same or slightly lower than the day temperature optimum. The allowable ranges are broad and include quite low night temperatures. Furthermore, the night allowable ranges in this experiment and in Helmers et al. (1970) do not overlap.

There are several possible reasons for the differences found between the two experiments. The Colorado seed source used by Helmers was from an elevation at least 200 m higher than any of the others. There is enough difference in behavior between the Wyoming and New Mexico sources within this study to make it plausible

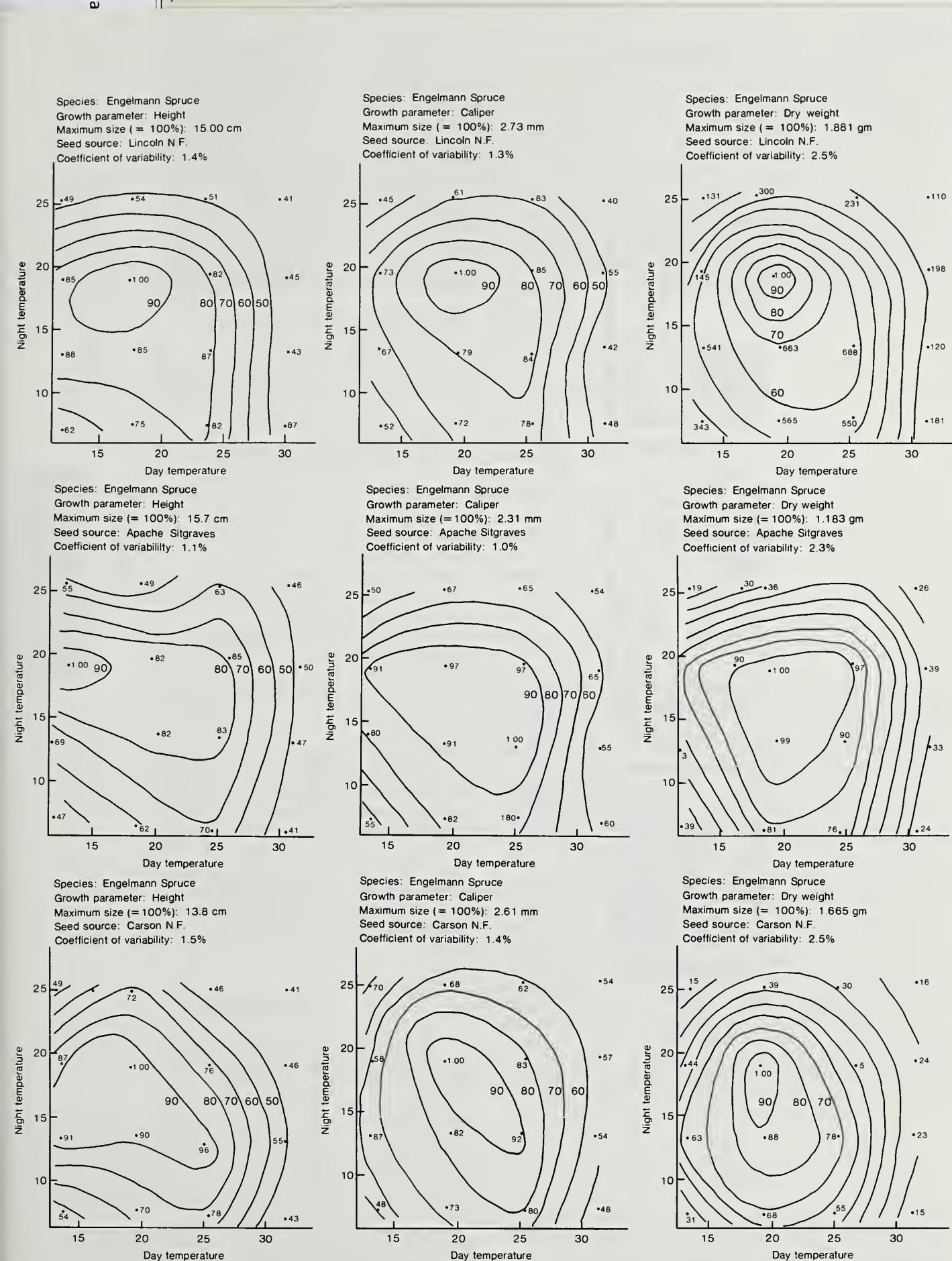
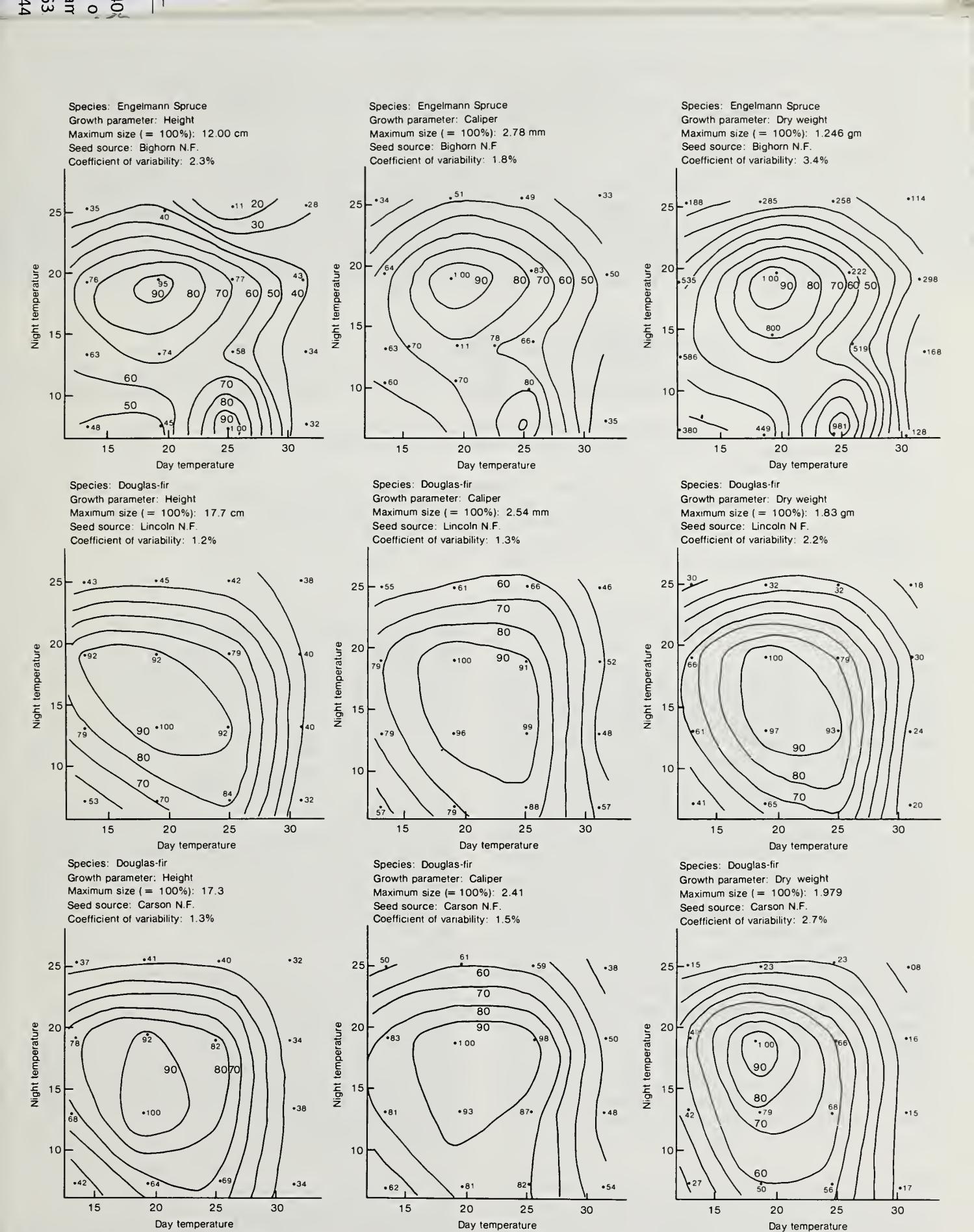


Figure 1.—Growth (in percent of maximum) of Douglas-fir and Engelmann



spruce of various seed sources as a function of day and night temperature.

Table 1.—Recommended temperature settings (°C) for maximum growth of tree seedlings from end of germination to dry weight indicated when all other environmental conditions are optimized

| Species | Seed source | Elevation | Maximum dry weight | Day temperature | | Night temperature | |
|--|---------------------|-----------|--------------------|-----------------|-----------------|-------------------|-----------------|
| | | | | Set point | Allowable range | Set point | Allowable range |
| <i>Picea engelmannii</i> (Parry) | Sheridan, Wyo. | 2,800 | 1.25 | 20 or 25 | 15-24 22-27 | 18 7 | 13-21 5-11 |
| <i>Picea engelmannii</i> (Parry) | Taos, N. Mex. | 2,940 | 1.67 | 19 | 15-25 | 17 | 8-22 |
| <i>Picea engelmannii</i> (Parry) | McNary, Ariz. | 2,800 + | 1.18 | 18 | 13-27 | 16 | 7-22 |
| <i>Picea engelmannii</i> (Parry) | Mayhill, N. Mex. | 2,900 | 1.88 | 19 | 15-25 | 19 | 10-22 |
| <i>Picea engelmannii</i> (Parry) ¹ | Larimer Co., Colo. | 3,140 | 8.3 | 19 | 17-23 | 23 | 22-24 |
| <i>Pseudotsuga menziesii</i> var. <i>glauca</i> (Beissn.) Franco | Taos, N. Mex. | 2,940 | 1.98 | 19 | 14-26 | 18 | 10-21 |
| <i>Pseudotsuga menziesii</i> var. <i>glauca</i> (Beissn.) Franco | Cloudcroft, N. Mex. | 2,600 | 1.83 | 20 | 15-27 | 16 | 8-21 |
| <i>Pseudotsuga menziesii</i> var. <i>menziesii</i> (Mirb.) Franco ² | Vancouver Is., B.C. | — | 2.4 | 22 | 17-25 | 18 | 13-22 |
| <i>Pinus ponderosa</i> var. <i>scopulorum</i> Engelm. ³ | Ruidoso, N. Mex. | 2,400 | 19.1 | 22 | 18-26 | 24 | 18-25 |

¹Helmers et al. 1970.

²Brix 1971.

³Tinus and McDonald 1979.

that the combination of higher elevation and a different seed source remote from the others would account for the difference.

The seedlings in the Helmers et al. (1970) study were raised to a dry weight about five times that in this study. There is evidence from other studies that temperature optima are not necessarily the same at different ages and sizes (Tinus and McDonald 1979).

Finally, the conditions of the experiment greatly affect the results. Because this study was designed to provide information useful to greenhouse nursery operators, conditions other than temperature were selected accordingly. These conditions were quite different than in the Helmers et al. (1970) experiment. This also underscores the need to match conditions in the experiment designed to gather information and the conditions under which the information will be used (Tinus and McDonald 1979).

The behavior of the two New Mexico sources of Douglas-fir was very similar to that reported for a Vancouver Island, B.C. source (table 1), and also to that of Engelmann spruce. Therefore, these two species are compatible and can be grown together in the same greenhouse.

A New Mexico source of ponderosa pine is included in table 1 for comparison, because in Rocky Mountain nurseries, ponderosa pine is a likely associate in the

same crop. It requires generally warmer temperatures than Engelmann spruce or Douglas-fir, especially at night. Because a greenhouse programmed for ponderosa pine will be too warm for spruce and fir, these species should be grown separately from the pine.

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